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SPEECH DISCRIMINATION IN NOISE AND HEAR-
ING LOSS AT 3000 HERTZ

Thomas Murry, et al

Naval Submarine Medical Research Laboratory
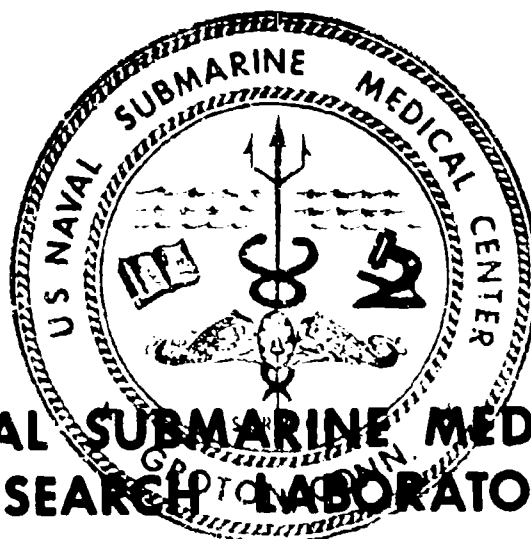Groton, Connecticut

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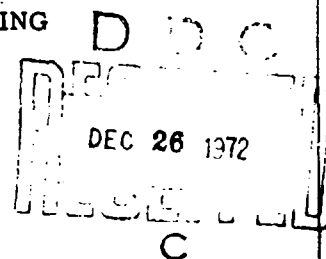
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SPEECH DISCRIMINATION IN NOISE AND HEARING
LOSS AT 3000 HERTZ

by

Thomas Murry, Ph.D.
and
Paul G. Lacroix

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Bureau of Medicine and Surgery, Navy Department
Research Work Unit M4305.08-3003DAC9.07

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13. ABSTRACT

Navy personnel with normal hearing and with hearing losses at 3 kHz and above were evaluated on tests of speech discrimination in noise. Two tests were used, one previously designed for use in audiological clinics and one constructed at this laboratory with background noise similar to that found in the enginerooms of nuclear submarines. The results indicate that subjects with hearing losses at 3 kHz and above may score as much as 11 per cent but more generally at least five per cent below normals for a speech discrimination task in noise. For the two types of noise used in these tests, there was little or no difference in the general trend of test results. The correlation coefficients obtained between the pure tone audiometric findings and the speech discrimination task in noise were found to be nonsignificant for the most part. From these results, it appears that hearing loss at 3 kHz reduces one's ability to discriminate speech in noise but this reduction is minor.

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	ROLE	WT	ROLE	WT	ROLE	WT
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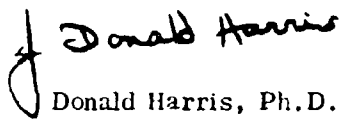
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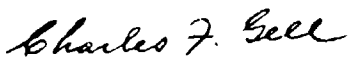
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SUMMARY PAGE

THE PROBLEM

To determine the effects of hearing loss at 3 kHz and above on speech discrimination tasks in noise.

THE FINDINGS

Mean discrimination scores ranged from 5 to 11 per cent lower for the subjects with hearing losses at 3 kHz and above. There was little relationship between the pure tone audiometric data and tests of speech discrimination in noise at suprathreshold levels.

APPLICATION

The results of this report provide information for use in evaluating current audiometric standards used by the Navy in selecting and rejecting candidates for submarine training.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Bureau of Medicine and Surgery Research Work Unit M4305.08-3003DAC9 — Validation of speech Audiometry in Submarines. It was approved for publication on 11 July 1972 and designated as NAVSUBMEDRSCHLAB Report No. 719. It is report No. 7 in this work unit.

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SPEECH DISCRIMINATION IN NOISE AND HEARING
LOSS AT 3000 HERTZ

INTRODUCTION

The increased interest in environmental noise problems has prompted the need for further evaluations of speech discrimination ability in noise, that is, speech in the everyday listening situation. Over recent years, numerous proposals for predicting discrimination ability which make use of the pure-tone audiogram have been suggested; most of these have been historically reviewed by Harris, Haines & Myers[1]. In addition to using pure-tone audiometry for such purposes, speech reception threshold testing has also been employed. Previous experimentation[2] would suggest, however, that the speech reception threshold test (SRT) is not necessarily a good predictor of one's ability to discriminate speech at suprathreshold levels. Moreover, the addition of distortions to the speech signal in the form of noise, filtering, or clipping would only tend to compound the problems of relating discrimination ability to threshold measures of speech identification.[3]

The relationship between the pure-tone audiogram and distorted (speeded in words/min) speech presented at suprathreshold levels was examined.[4] The conclusion was that about 15 per cent of the cues for sentence intelligibility are dependent upon the 3 kHz region of hearing; it was suggested that the simple arithmetic average audiometric loss at 1000, 2000, and 3000 Hz provided a good estimate of one's ability for understanding speeded speech. A

similar conclusion for speech distorted by noise was made by Kryter, Williams & Green.[5] They found a significant increase in the correlation coefficient between speech discrimination tests and audiometric data when the results at 3 kHz were used. Both reports emphasize the importance of the pure-tone audiometric data at 3000 Hz for use in estimating suprathreshold speech discrimination ability. However, pure-tone audiometry continues to be imprecise for predicting an individual's ability in speech discrimination tasks; Information as to the type of hearing loss provides additional information for such predictive procedures.

The use of a simple arithmetic average of pure-tone testing results at 1, 2, and 3 kHz may be highly questionable in evaluating certain hearing losses. Specifically, exposure to noise produces an audiometric contour which often shows hearing to be normal at frequencies up to 2000 Hz but with a sharp decrement at 3000 Hz. Averaging the three frequencies in these cases would tend to reduce the overall importance of 3 kHz.

It is the purpose of this report to describe the results of an experiment of speech discrimination in noise on subjects with hearing losses at 3 kHz and above and to assess the importance of hearing at 3 kHz for speech discrimination in a noisy environment, in particular the noise encountered by the nuclear submariner.

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PROCEDURE

For this investigation, a speech discrimination test in a background of nuclear submarine engineroom noise was constructed. This test was then used to evaluate a group with a hearing loss characteristic of the type resulting from exposure to noise, and a control group of normal-hearing listeners. The results of these tests were compared with data previously obtained using the same test format of speech discrimination but embedded in a somewhat different noise.

A. Test Construction

A speech discrimination test in noise was constructed using the Modified Rhyme Test[6] (as altered by Kreul et. al.[7]) but mixed with noise shaped to match a noise spectrum typically found in the enginerooms of nuclear submarines.[8] The test was used primarily to compare the effects on speech discrimination of engineroom noise with the more standard USASI* noise.[9] Construction of the test was similar in most aspects to the one constructed by Kreul and others.[7] The test consisted of four word lists, A, B, D, and E, from the Modified Rhyme Test. One male talker with previous recording experience recorded the lists onto a master tape. This was done using an Altec 681-A microphone and an Ampex 300C Magnetic Tape Recorder. Each word was embedded in the carrier phrase: "Number_____, You will mark the

_____ please." In order to maintain a constant speech level, both the talker and the experimenter monitored individual VU meters, the meter on the tape recorder and a second meter driven by the monitor circuit of the tape recorder. Several practice sessions were required before the talker made the recordings. During the final recordings, the entire list was rerecorded if the talker did not maintain the designated level for the word mark. Six seconds separated homologous points of any two test items.

After the four lists were recorded, they were processed through a General Radio Graphic Level Recorder to verify the visual VU observations. No deviation greater than $\pm$ 1 dB of the word mark, was accepted. Thus, the word mark for the final set of four lists was within $\pm$ 1 dB of the VU target. When the list was accepted, a 10-sec calibration tone of 1000 Hertz was recorded at the beginning of the tape.

The variations of the actual test words for each list were next determined. As might be expected, the actual levels of the test words varied due to their phonemic construction. The graphic level tracings were used to obtain the peak intensities in the test words. The average intensity of the test words on the four lists ranged from 6.2 to 8.5 dB greater than the word mark. The graphic level tracings of the test words provided a basis for mixing noise with the speech.

The masking noise used in the construction of the test tape is shown in Figure 1. For comparison, the shape of the noise used by Kreul et. al.[7] is
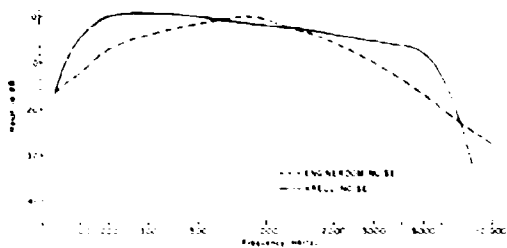
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Fig. 1. Contours of the two types of noise used in speech discrimination tests.

also shown. A Grason-Stadler Model 455B Noise Generator and a General Radio Model 1925 Multifilter with a rejection rate of 36 dB/octave were used to shape the noise shown in Figure 1. The noise was recorded on an Ampex Model 300C tape recorder. The filter was adjusted to compensate for the characteristics of the tape recorder and a TDH 39 earphone with MX 41/AR cushion which was used in all subject testing. Thus, the curve shown in Figure 1 represents the output of the earphone recorded through a 6 cc coupler and a General Radio Model 1551C sound level meter fitted with a P-5 microphone.

For the speech discrimination test, three S/N levels were desired. Essentially, a trial and error method was used to determine the final S/N levels. Previous data obtained by Sergeant and McKay[10] indicated that voltage S/N levels of + 25, -4, and -10 would produce the desired range of scores. Using a Ballantine voltmeter, the noise and speech each on one channel of the Ampex tape recorder were mixed and played to panels consisting of 10 men having normal hearing (no loss from 500 to 3000 Hz greater than 15 and no

loss to 6000 greater than 20 dB re: .0002 dynes/cm^2). The lists were presented monaurally to 8 groups of subjects; final S/N levels of +25, -5, and -11 were selected, yielding results in Table I.

A final tape, used for all speech discrimination tests, was constructed by recording the signal and the noise at these S/N ratios onto a single channel of a second Ampex 300C tape recorder. This tape was presented to 10 more men meeting the same audiometric criteria as the initial 80 as a means of verifying that the rerecording from one machine to the second did not appreciably alter the signal. This group of 10 men produced mean scores of 96, 80, 58.4, and 94 per cent for the four lists respectively, i.e., rerecording had not significantly altered conditions.

B. Selection of Subjects.

The control group (MRT/EN Normal) consisted of 20 young men with normal hearing (15 dB ISO or better) at .5, 1, 2, and 3 kHz and 20 dB or better ISO at 4 and 6 kHz. The experimental group (MRT/EN Hearing Loss) had essentially normal audiograms at .5, 1 and 2 kHz but at least a 25 dB difference between their thresholds at 2 kHz and 3 kHz (see Figure 2, Tables II, III).

All Ss were given a speech reception threshold (SRT) test using the Phonetically Balance Word Lists (PB)[11]. The playback level of the MRT tests was set 40 dB re SRT with the 1000 Hertz calibration.

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Table I. Final Test Tape for Speech Discrimination Testing
with Background Engineroom Noise.

MRT List	S/N (Voltage)	Mean Score (%)	Range
A	+25	96	92 - 100
B	-5	79.4	77 - 84
D	-11	56	46 - 62
E	+25	92.8	89 - 96

NOTE: Difference between means for lists A vs E not significant.
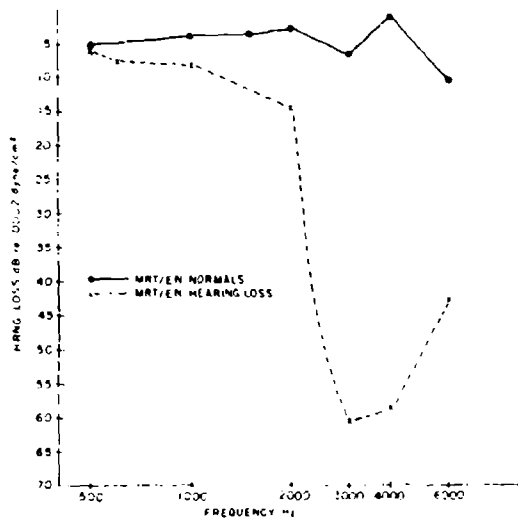
Fig. 2. Group audiograms for the two groups of test subjects.

C. Determination of Masking Pattern of Noise Used.

It was desired to simulate workspace noise as commonly found in submarines, but it was also desirable to determine whether such a noise would differ in its effect on the ear from the noise used on tapes now being widely used in speech testing. [The latter noise closely resembles USASI noise (for spectrum see p. 600, Stevens [9]. If it should yield speech-masking data comparable to those from the noise used in creating the tape for this study, we would in subsequent studies utilize only the standard noise.

Twenty normal-hearing enlisted men (not those of the group above) were each

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Table II. Normal Hearing Group (MRT/EN).

Subject Number	Pure Tone Audiometric Data (ISO)								PB SRT	MRT/EN (% correct)			
	500	1000	1500	2000	3000	4000	6000	8000		A	B	D	E
1	5	0	0	0	0	0	10	0	-8	100	86	62	98
2	0	0	0	0	0	0	5	5	-4	96	80	66	96
3	5	5	5	5	5	0	5	0	0	98	80	54	94
4	5	0	10	5	10	0	15	5	+6	96	72	48	98
5	15	5	5	0	5	10	10	0	-4	96	78	44	96
6	0	5	5	5	10	15	20	15	+2	96	80	48	94
7	10	0	0	10	5	0	20	0	+2	92	78	48	96
8	10	0	0	0	10	0	10	0	0	98	80	68	100
9	10	10	5	0	10	0	10	10	+2	96	74	56	94
10	10	10	10	5	10	0	10	0	02	98	78	50	98
11	5	0	0	0	0	0	5	5	+2	98	88	46	96
12	0	0	0	0	0	0	10	0	+2	96	78	50	94
13	10	5	5	5	10	5	10	0	+2	94	84	58	96
14	0	0	0	0	5	0	5	0	+2	98	72	48	98
15	5	0	0	0	0	0	10	0	-4	98	78	62	98
16	0	10	10	10	10	0	15	20	+2	96	74	66	92
17	5	0	0	5	0	0	15	0	-2	98	80	56	90
18	0	10	5	0	15	0	0	0	-4	96	82	62	98
19	0	5	0	0	15	5	15	0	-4	98	80	56	96
20	5	10	10	5	15	0	15	0	0	98	70	46	96
MEAN	5.0	3.7	3.5	2.7	6.7	1.7	10.7	3.0	.70	96.9	78.6	54.7	95.9
S.D.	4.6	4.3	4.0	3.4	5.4	4.1	5.2	5.7	1.9	1.7	4.5	7.4	2.3

Table III. Hearing Loss Group (MRT/EN).

Subject Number	Pure Tone Audiometric Data (ISO)								PB SRT	MRT/EN (% correct)			
	500	1000	1500	2000	3000	4000	6000	8000		A	B	D	E
1	10	10	10	10	65	65	60	50	8	88	50	38	88
2	10	5	5	45	85	85	90	90	12	86	50	44	84
3	10	10	0	10	50	40	30	0	6	96	78	46	92
4	0	5	5	5	60	90	95	NR	4	94	66	58	88
5	0	10	0	5	45	25	25	0	6	96	78	52	94
6	0	0	5	0	45	35	20	0	8	96	72	62	96
7	0	0	5	0	50	20	10	0	6	92	72	38	96
8	0	0	0	0	40	75	70	50	4	88	76	48	90
9	5	5	10	15	75	80	50	NR	2	88	64	46	86
10	15	5	10	20	60	60	55	35	0	90	66	42	94
11	0	10	10	10	70	60	30	30	4	98	76	42	92
12	15	15	10	25	55	55	55	20	12	94	60	44	94
13	10	10	10	5	75	NR	NR	NR	10	94	64	44	92
14	10	10	10	10	60	55	40	10	6	98	78	56	96
15	0	5	15	15	55	50	70	40	6	90	62	42	82
16	10	10	10	35	60	55	60	55	6	86	58	46	90
17	10	10	10	15	75	75	NR	NR	4	94	56	44	86
18	5	5	10	15	45	40	25	5	2	96	82	68	96
19	15	20	25	45	90	80	90	40	12	88	68	48	90
20	0	10	5	5	45	60	75	50	6	94	74	66	92
MEAN	6.2	7.7	8.2	14.5	60.2	60.0	58.5	42.7	6.2	92.3	67.5	48.7	90.9
S.D.	5.7	4.9	5.5	13.2	13.9	20.6	27.4	34.7	3.3	3.9	9.3	8.6	4.0

given pulsed Bekesy audiometry in quiet; 10 were again tested using one of the two noises at a relatively weak and again approximately at that level used with other Ss for speech tests; the other 10 were given the other noise. Individual masking curves were drawn by comparing each masked tracing with its control in quiet.

RESULTS

Table IV shows the mean in per cent words correct and standard deviations. Data by Sergeant and Murry[12] and Myers and Angermeier[13] is also shown for comparison of the same test but with different masking noise. Figure 3 shows that the normal-hearing group scored higher than the hearing loss group under all test conditions. The difference between the groups was approximately 5% in the +25, 6% in the -1i, and 11.1% in the -5 S/N test.

Data by Sergeant and Murry[12] and Myers and Angermeier[13] shown in the lower half of Table IV indicates that the USASI noise and the engineroom noise produced small differences between normal and hearing loss subjects on

Table IV. Means for Standard Deviation for the Speech Discrimination Tests for the Four Groups of Subjects.

Word Lists		Normal Hearing		Hearing Loss	
		Mean	S.D.	Mean	S.D.
MRT/EN	A	96.9	1.7	92.3	3.3
	B	78.6	4.5	67.5	9.3
	D	54.7	7.4	48.7	8.6
	E	95.9	2.3	90.9	4.0
MRT/N*	B	94.3	3.2	90.3	7.5
	F	74.4	6.4	69.0	9.5
	D	72.8	5.9	66.3	6.0
	E	95.2	3.0	89.8	6.9

*The normal hearing group data from the lower half of this table is taken from Sergeant and Murry.[12] The hearing loss data for the lower half of the table is taken from Myers and Angermeier.[13]
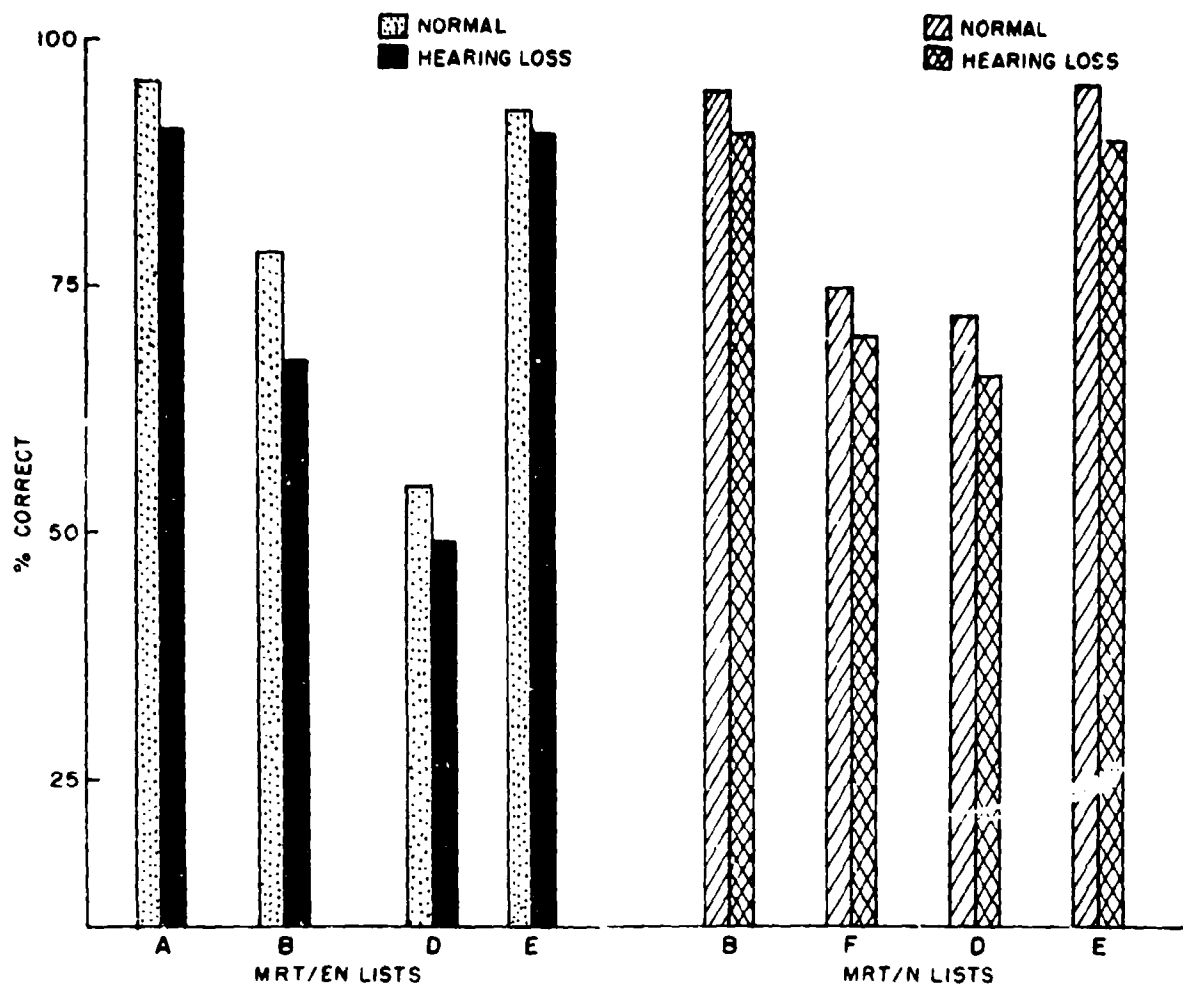
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Fig. 3. Group averages plotted for the four MRT word lists presented to each test group.

the discrimination tests; that is, the differences in the noise spectra did not have a significant bearing on the outcome of the tests of speech discrimination in noise.

These results suggest that men with normal hearing at 2 kHz but with losses at 3 kHz and above perform about 5-10 percentage points poorer than normal-hearing subjects on such tests.

Pearson r's (see Table V) were computed for the hearing-loss group using the pure tone thresholds at 1, 2, and 3 kHz, the SRT score and the four MRT test lists (audiometric ranges are too slight with normal listeners to render utile the r). The correlations between audiometric data vs MRT score approach reliability (P = .05) for the easy lists when 3 kHz is added to the formula, but this is not true for the difficult lists.

Table V. Correlation Matrix for the MRT/EN Hearing Loss Subjects Among the Speech Discrimination and Audiometric Test Results.

	SRT PB	LIST A	LIST B	LIST D	LIST E	AVE 1,2 KHz	AVE 1,2,3	AVE 3 KHz
		-.35	-.14	-.20	-.35	.54	.57	.25
LIST A			.89	.82	.98	-.20	-.47	-.26
LIST B				.84	.90	-.03	-.21	-.17
LIST D					.81	-.11	-.24	-.22
LIST E						-.23	-.46	-.28

$$p \quad .44 = .05$$

$$p \quad .56 = .01$$

No tests of acuity in quiet used in this study, either with pure tones or with speech, bears any significant relation to these close simulations of military communications in noisy workspaces.

Figure 4 is a scattergram for the worst-case noise list vs audiometric data. It is manifestly impossible from such data as in Fig. 4 to predict speech discrimination ability in noise from pure-tone or speech audiometry.

The question whether these results would have been obtained had we used the standard USASI noise, can probably be answered affirmatively. Data from Table IV lend credence to this assertion. Figure 1 showed that the spectra are not widely divergent, though the
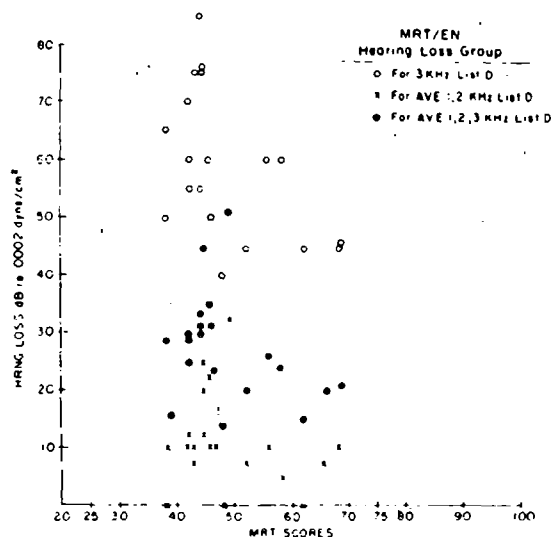

Fig. 4. Scatter diagrams showing the relationship between three pure tone audiometric threshold scores and scores on MRT, List D with the engineroom noise background.

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USASI noise is about 10 dB more intense at 5 kHz. Figure 5 shows that the asymmetric nature of masking has smoothed these differences out such tha that the psychoacoustic masking effects on either pure tones or speech would be predicted to be indistinguishable. There is little more than face validity in our case for the exact reproduction of submarine noise, and the use of the standard tapes is indicated.

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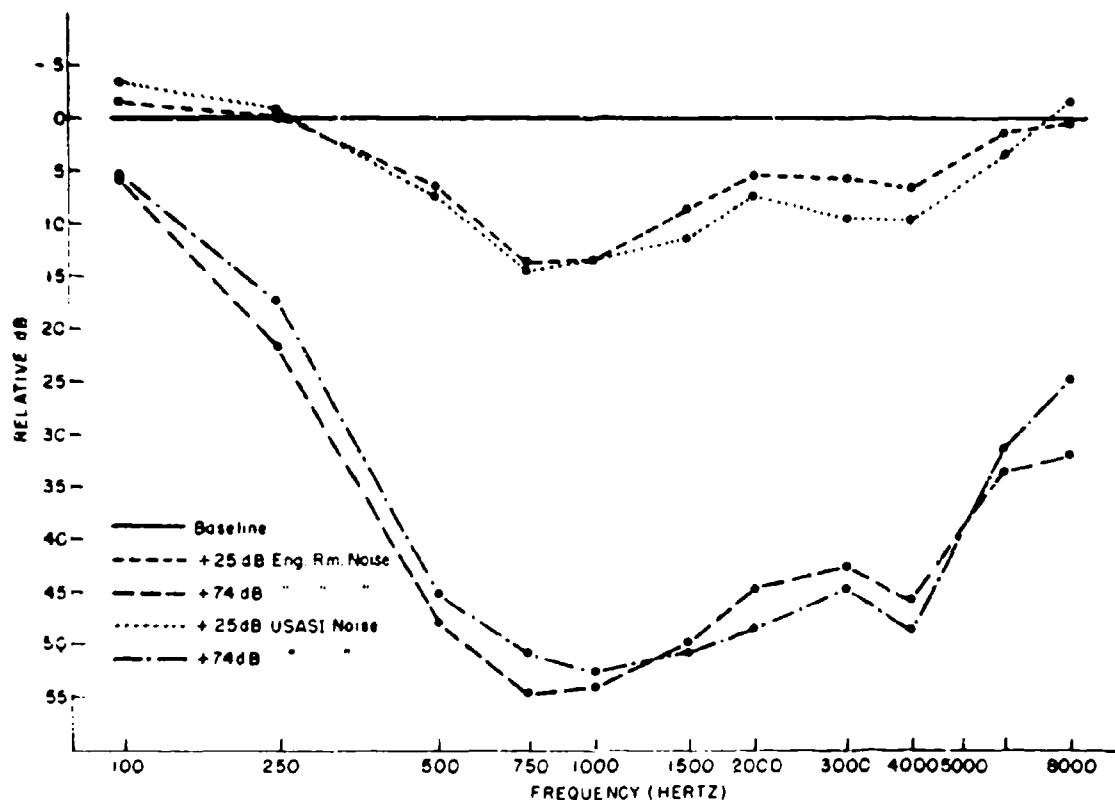
Fig. 5. Masking contours for two types of noise presented at two suprathreshold levels.

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